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MATHEMATICAL MODEL AND IMPLEMENTATION OF CONTROLLING THE BEHAVIOR OF COMPUTERIZED PRODUCTION SYSTEM EMPLOYEES

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Abstract. *When creating a mathematical model of controlling the behavior of employees in computerized production systems, the issues of building effective software systems for protection against internal attacks, which have features such as flexibility, were considered. In computerized production systems, the management and consolidation of initial data from the registration logs and operating system protocols, data presentation and storage methods are analyzed separately. The architecture of the consolidation system of computerized production is proposed. It is proposed to use digital technology to analyze and synthesize the collected data about the subject's activity in the computerized production system and to build a mathematical model of subjects' behavior based on associative rules. The constructed mathematical model can be visually presented to the administrator of the computerized production system as a network of dependencies, and can also be used to analyze anomalies in the behavior of system participants and to assess the level of potential threat arising from each subject.*

Keywords: *computerized production system, digital technologies, employee behavior control, mathematical model.*

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ И ВНЕДРЕНИЕ КОНТРОЛЯ ПОВЕДЕНИЯ СОТРУДНИКОВ КОМПЬЮТЕРИЗИРОВАННОЙ ПРОИЗВОДСТВЕННОЙ СИСТЕМЫ

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Аннотация. *При создании математической модели управления поведением сотрудников в компьютеризированных производственных системах были рассмотрены вопросы построения эффективных программных систем защиты от внутренних атак, обладающих такими особенностями, как гибкость. В компьютеризированных производственных системах отдельно анализируются управление и консолидация исходных данных из журналов регистрации и протоколов операционной системы, способы представления и хранения данных. Предложена архитектура системы консолидации компьютеризированного производства. Предлагается использовать цифровые технологии для анализа и синтеза собранных данных о деятельности субъекта в компьютеризированной производственной системе и построения математической модели поведения субъектов на основе ассоциативных правил. Построенная математическая модель может быть наглядно представлена администратору компьютеризированной производственной системы в виде сети зависимостей, а также может быть использована для анализа аномалий в поведении участников системы и оценки уровня потенциальной угрозы, исходящей от каждого субъекта.*

Ключевые слова: *компьютеризированная производственная система, цифровые технологии, управление поведением сотрудников, математическая модель.*

KOMPYUTERLASHTIRILGAN ISHLAB CHIQARISH TIZIMI XODIMLARINING HATTI-HARAKATINI NAZORAT QILISHNING MATEMATIK MODELI VA UNING TADBIQI

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Annotatsiya. *Kompyuterlashgan ishlab chiqarish tizimlarida hodimlar hatti-harakatIarini nazoratga olishning matematik modelini yaratishda ichki hujumlardan himoya qilish uchun samarali dasturiy tizimlarni qurish masalalari ko‘rib chiqilgan bo‘lib, moslashuvchanlik kabi xususiyatlarga ega. Kompyuterlashgan ishlab chiqarish tizimlarida ro‘yxatga olish jurnallari va operatsion tizim protokollaridan dastlabki ma’lumotlarni boshqarilishini va konsolidatsiya qilishni, ma’lumotlarni vaqt oraliqida taqdim etish, va saqlash usullari alohida tahlil qilingan. Kompyuterlashgan ishlab chiqarishning konsolidatsiya tizimi arxitekturasi taklif etilgan. Kompyuterlashgan ishlab*

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chiqarish tizimida subyekt faoliyati haqidagi to'plangan ma'lumotlarni analiz va sintez qilish uchun raqamli texnologiyasini qo'llash usullari va subyektlar xulq-atvor matematik modelini assotsiativ qoidalar asosida qurish taklif qilingan. Qurilgan matematik modeli kompyuterlashgan ishlab chiqarish tizimi administratoriga vizual tarzda bog'liqliklar tarmog'i sifatida taqdim etilishi, shuningdek, tizim ishtirokchilari hatti-harakatlaridagi anomaliyalarni analiz qilishda va har bir subyektdan kelib chiqadigan potentsial tahdid darajasini baholash uchun foydalanilishi mumkin.

Kalit so'zlar: *kompyuterlashtirilgan ishlab chiqarish tizimi, raqamli texnologiyalar, hodimlar hatti-harakatini nazoratga olish, matematik model.*

Introduction. The advancement of digital technologies in production systems and their widespread adoption have significantly transformed the industrial landscape. These changes, coupled with the rapid growth in the volume and value of critical data stored within industries, underscore the need for robust data protection measures. In contemporary industrial environments, the most severe threats to data security are posed by attacks on computerized production systems [1-3]. These systems, integral to modern manufacturing and operational processes, are particularly vulnerable to unauthorized intrusions and manipulations.

An attack (or breach) on a computerized production system refers to any unauthorized activity, whether initiated by a human or a malicious software, that compromises the integrity, confidentiality, or availability of data critical to industrial operations. Such breaches can disrupt production processes, lead to significant financial losses, and damage an organization's reputation [4-7]. While external threats are a concern, it is the internal attacks—those perpetrated by insiders—that often cause the most substantial harm. These insiders, who may have legitimate access rights to the computerized production system (Fig. 1), can exploit their positions to cause damage deliberately. This makes internal threats particularly dangerous, as they can be more challenging to detect and prevent.

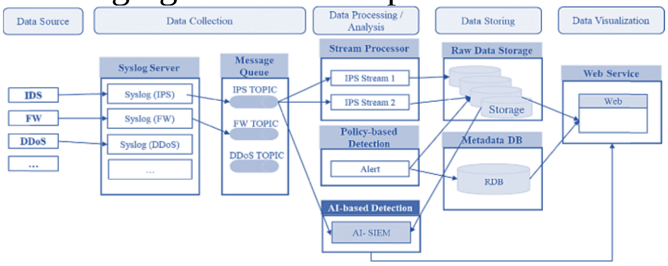

Fig.1. The main stages of the process of working with digital data in the computerized production system.

To combat these threats, computerized production systems traditionally utilize intrusion detection systems (IDS). The fundamental principle of these IDS solutions [8-11] is to compare event logs generated within the production system against established patterns or mathematical models that describe various attack vectors using a set of predefined rules. However, the effectiveness of these systems is often limited by their reliance on fixed rules, which are typically defined by security experts. Consequently, they may not be responsive or adaptive to emerging or previously unknown types of attacks. For the IDS to identify new attack patterns, experts must continuously update the mathematical models with new rules—a process that is both time-consuming and dependent on the availability of skilled personnel.

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These limitations highlight a significant challenge: the need for more adaptive, autonomous systems capable of identifying and mitigating threats without requiring constant human intervention. In practice, traditional systems often employ techniques such as periodic reviews of audit logs (log files) and application behaviors, collected by the computerized production system, to detect any anomalies or unauthorized activities. However, this approach necessitates the development of mathematical model rules tailored to each specific type of log, which can be a resource-intensive task.

In the current landscape, where the complexity and sophistication of cyber threats [12-15] are continually evolving, there is an urgent need to develop more effective computerized production systems. These systems must be designed with characteristics such as independence, allowing them to operate and respond autonomously to threats without relying solely on pre-set rules or human intervention. Furthermore, they must possess a high degree of adaptability, enabling them to recognize and respond to new and emerging threats dynamically. Such capabilities are essential not only for protecting the integrity of industrial data but also for ensuring the uninterrupted operation of production processses and safeguarding the broader industrial ecosystem.

To address these challenges, modern cybersecurity strategies in industrial settings are increasingly focusing on integrating advanced technologies such as machine learning and artificial intelligence. These technologies can analyze vast amounts of data in real-time, learn from new patterns of behavior, and predict potential threats with greater accuracy. By leveraging these advanced analytics, production systems can not only detect anomalies more effectively but also anticipate possible breaches before they occur. This proactive approach to security is critical in minimizing the risk of internal attacks and enhancing the overall resilience of computerized production systems.

Literature review. Moreover, the adoption of a layered security approach, which involves multiple defensive mechanisms working in concert, can further strengthen the security posture of these systems. This might include combining traditional IDS with advanced threat detection tools, implementing robust access controls, and ensuring regular system updates and patches to address vulnerabilities promptly (Fig. 2). Together, these measures create a more robust defense against both external and internal threats, safeguarding the industry's vital data and maintaining the integrity of production processes.

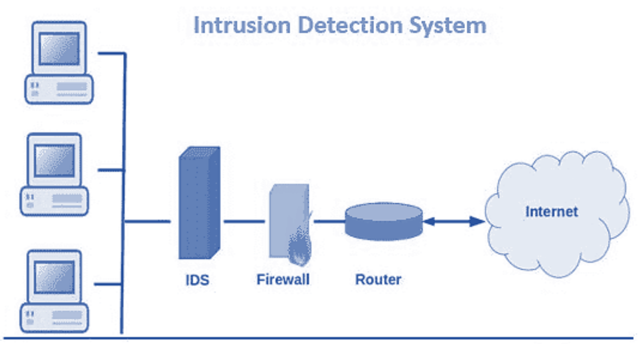

Fig.2. The structure of the threat detection process in the computerized production system.

The evolving nature of threats to computerized production systems necessitates a comprehensive and dynamic approach to cybersecurity. As digital technologies continue to advance and become more integrated into industrial operations,

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the importance of developing sophisticated, adaptive, and autonomous security solutions will only grow. By embracing these advanced security strategies, industries can better protect their critical assets, ensure operational continuity, and maintain a competitive edge in an increasingly digital world.

Results. In a computerized production system, the framework for monitoring and analyzing user and system behavior is crucial for maintaining operational security, efficiency, and integrity. This framework is designed to systematically collect data from various sources within the production environment, compile comprehensive statistical reports, and analyze the accumulated industrial data to identify patterns, trends, and potential anomalies. The primary objective of such a system is to ensure that all operational activities align with the expected standards and that any deviations are promptly detected and addressed.

The data collection process in a computerized production system involves multiple layers of monitoring, which capture information from different operational aspects. This includes real-time logging of user actions, system events, software interactions, and network communications. The collected data is then stored in a centralized database, where it is processed and organized for further analysis. Statistical reporting is an essential component of this process, providing a quantitative overview of the system's performance, user behavior, and the overall health of the production environment. These reports are crucial for identifying long-term trends, assessing the effectiveness of security measures, and making informed decisions about future improvements.

One of the critical features of this system is its ability to construct associations and mathematical models that help in understanding the relationships between different variables and predicting future outcomes. These models are used to analyze anomalies—deviations from the norm that could indicate potential security breaches, system failures, or inefficiencies in the production process. Anomalies can be detected at various levels, from individual components within a single computerized production system to broader patterns that affect the entire network. For instance, unusual patterns of data access or modifications may suggest insider threats, while unexpected network traffic could indicate an external cyberattack.

The multi-agent architecture of a computerized manufacturing system plays a vital role in its ability to manage complex and dynamic production environments. A multi-agent system consists of several autonomous agents, each responsible for specific tasks, such as data collection, analysis, decision-making, and response actions. This decentralized approach allows the system to operate more efficiently and adapt to changing conditions without relying on a central control unit. Each agent operates independently but communicates with others to share information and coordinate actions, ensuring a cohesive and integrated response to any detected anomalies or threats.

Operating system and software logs are fundamental to the functioning of a computerized production system, serving as primary sources of industrial information. These logs provide a detailed, chronological record of all system activities, including user logins, file accesses, process executions, and network connections. By analyzing these logs, the system can identify patterns of

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normal behavior and detect any deviations that may indicate a security incident or operational problem. For example, a sudden increase in failed login attempts could suggest a brute force attack, while unexpected changes in system configuration files might indicate tampering or malware activity (Fig. 3).

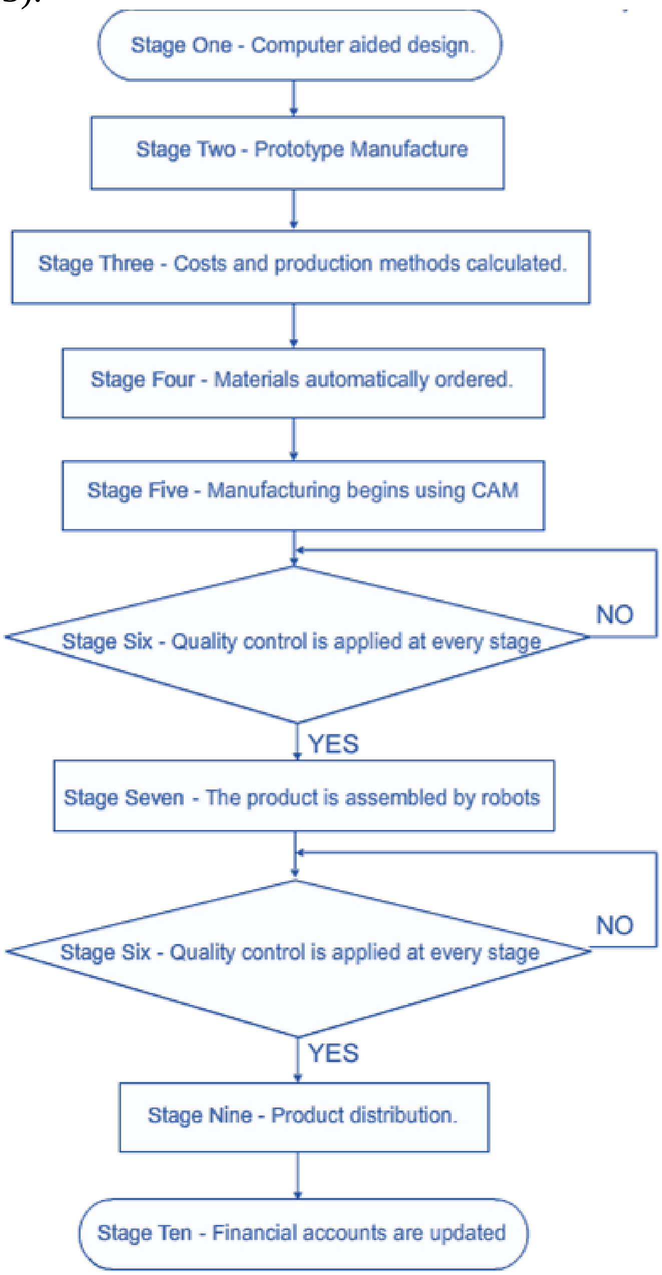

Fig.3. Algorithmic block scheme of the operation of a computerized production system.

The integration of advanced data analysis techniques, such as machine learning and artificial intelligence, enhances the system's ability to detect and respond to threats in real time. Machine learning algorithms can be trained on historical data to recognize normal behavior patterns and identify subtle deviations that might go unnoticed by traditional rule-based systems. Artificial intelligence can further improve decision-making processes by simulating different scenarios and predicting the potential impact of various actions. Together, these technologies enable a more proactive approach to security, allowing the system to anticipate and mitigate risks before they escalate into serious issues.

Furthermore, the system's ability to perform both dimensional and cross-dimensional analysis is crucial for comprehensive monitoring. Dimensional analysis focuses on specific aspects of the production process, such as machine performance or network security, while cross-dimensional analysis examines the interactions between different components and their cumulative impact on overall system performance. This holistic approach ensures that all potential vulnerabilities are identified and addressed, providing a more robust defense against both internal and external threats (Fig. 4).

In addition to security and threat detection, computerized production systems are also designed to optimize operational efficiency. By continuously monitoring and analyzing production processes, the system can identify bottlenecks, inefficiencies, and areas for improvement. This information can be used to adjust production schedules, allocate resources more effectively, and implement process improvements that en-

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hance productivity and reduce costs. For example, if the system detects that a particular machine is frequently causing delays due to maintenance issues, it can recommend a preventive maintenance schedule to minimize downtime and improve overall efficiency.

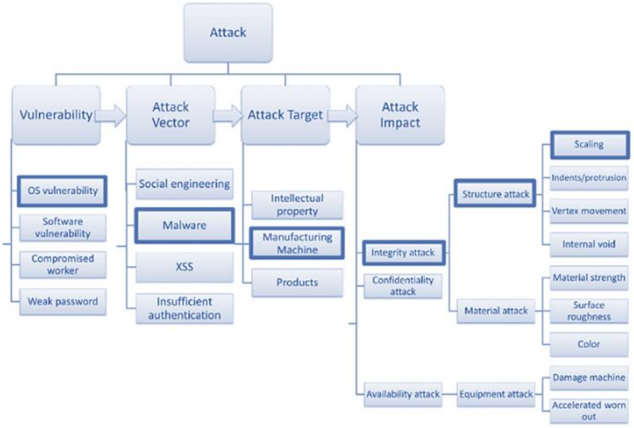

Fig.4. Attack Surface in the computerized production system.

Moreover, the system's flexibility and adaptability are key to its effectiveness in dynamic production environments. As production processes evolve and new technologies are integrated, the system must be able to adapt to these changes without significant reconfiguration or downtime. This requires a modular design that allows new components to be easily added or existing components to be modified without disrupting the overall operation. Additionally, the system must be capable of learning from past experiences and adjusting its behavior accordingly, ensuring continuous improvement and resilience in the face of emerging challenges.

The monitoring and analysis framework in a computerized production system is a comprehensive and multi-faceted solution that integrates data collection, statistical analysis, anomaly detection, and optimization to ensure the highest levels of security, efficiency, and operational integrity. By leveraging advanced technologies and a multi-agent architecture, these systems provide a robust defense against both internal and external threats while also supporting continuous improvement initiatives that drive productivity and competitiveness in the industrial sector.

Agents, as critical components within a computerized production system, are specifically designed to handle the complex task of data acquisition from a multitude of sources. They play a pivotal role in gathering industrial data related to various events captured in the operating system and software logs within the targeted computerized production environment. These events can range from routine system operations and user interactions to potential security incidents and system anomalies. The ability of agents to effectively capture and process this data is foundational to the overall functionality and security of the computerized production system.

Each agent is meticulously designed to ensure seamless interoperability with other components of the computerized manufacturing system. This interoperability is achieved by converting critical industrial data from diverse and heterogeneous sources into a standardized universal format. The standardization process is vital because it allows data from different sources—each potentially having its own structure and format—to be synthesized into a cohesive dataset that can be easily analyzed and utilized across the entire production system.

The universal format utilized by these agents is typically based on XML (eXtensible Markup Language). XML was chosen for its flexibility and robustness in handling complex data structures, allowing

for a standardized representation of diverse data types. This XML-based format facilitates the detailed analysis, synthesis, and consolidation of records from multiple sources into a unified view. Such a unified format is crucial for maintaining consistency and accuracy in data interpretation, enabling the system to perform comprehensive analyses that are essential for operational efficiency and security monitoring.

The process of data collection and transmission by the agents is carefully orchestrated to maximize the effectiveness of centralized monitoring and analysis. Once collected, the industrial data is transmitted to a consolidation server within the computerized production system. This transmission follows a predefined schedule, which can be configured based on the specific requirements of the production environment—ranging from real-time data streaming to batch processing at regular intervals. The consolidation server acts as a central hub where all incoming data is aggregated, processed, and stored, providing a single point of reference for all monitoring and analytical activities.

By centralizing the data, the system can leverage advanced analytical tools and algorithms to perform in-depth analysis, detect anomalies, predict potential issues, and optimize production processes. The consolidation server enables the system to maintain a comprehensive and up-to-date view of the entire production environment, supporting a range of functions from routine monitoring and maintenance to strategic decision-making and planning.

Furthermore, the agents' ability to standardize and consolidate data enhances the system's flexibility and adaptability. In a dynamic production environment, where changes in technology, processes, and personnel are frequent, the ability to quickly adapt to new data sources and formats without significant reconfiguration is invaluable. This adaptability ensures that the computerized production system can continue to operate efficiently and effectively, even as the industrial landscape evolves.

The collected data can also be used for historical analysis, providing valuable insights into long-term trends and patterns within the production environment. This historical perspective can help identify recurring issues, evaluate the effectiveness of past interventions, and inform future strategies for process improvement and risk management. By building a comprehensive database of past events and conditions, the computerized production system can enhance its predictive capabilities, allowing it to anticipate potential problems and take proactive measures to prevent them.

Moreover, the integration of machine learning and artificial intelligence within the system further augments its analytical capabilities. These advanced technologies can learn from historical data, identify subtle patterns and correlations, and develop predictive models that can foresee future events or anomalies. By continuously learning and adapting, the system can improve its accuracy and responsiveness over time, providing a more robust and reliable platform for industrial production.

In addition to their role in data collection and analysis, agents also contribute to the overall security architecture of the computerized production system. By continuously monitoring system activities and user behavior, agents can help detect potential security threats, such as unauthorized access attempts or abnormal data access

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patterns. When such threats are identified, the system can trigger automated responses, such as alerting administrators, isolating affected systems, or initiating countermeasures to mitigate the impact of the threat.

Agents serve as a vital element within a computerized production system, facilitating comprehensive data collection, standardization, and analysis. Through their ability to convert diverse industrial data into a unified format, transmit it to a central consolidation server, and support advanced analytical processes, agents enable a robust framework for monitoring, security, and optimization. Their role is indispensable in ensuring that the computerized production system remains resilient, efficient, and capable of meeting the complex demands of modern industrial environments.

The strategy for managing data within a computerized production system encompasses a range of methodologies designed to enhance both the efficiency and effectiveness of data transfer and processing. A critical component of this strategy involves the systematic transfer of industrial data to a consolidation server based on specific criteria. One prominent approach in this strategy is the transfer of a predetermined volume of industrial data or a specified number of log records. This method is engineered to optimize the utilization of agent resources by triggering the data transfer process only once the collected data meets a predefined threshold.

By utilizing this method, the frequency of data transfers is reduced, which significantly alleviates the load on network resources. This reduction in transfer frequency helps to prevent network congestion and ensures that the network's transmission capacity is utilized more effectively. The consolidation of large volumes of log records into fewer, larger data transfers facilitates a more manageable and streamlined approach to data transmission. This not only prevents the network from becoming overwhelmed but also ensures that data is transferred in a manner that is both efficient and effective (Fig. 5).

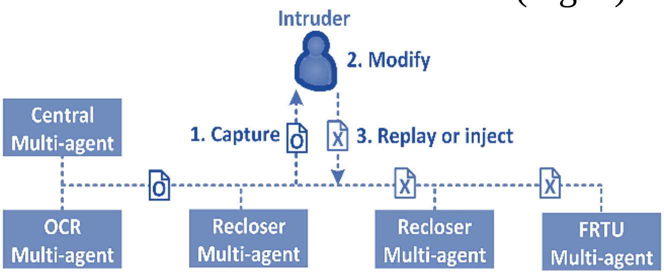

Fig.5. Performance of agents in the computerized production system.

The benefits of this approach extend beyond mere efficiency. By minimizing the number of data transfers, the system reduces the potential for errors and inconsistencies that can occur with more frequent, smaller transfers. Additionally, this method supports better resource management, as it allows for more predictable and controlled data handling processes. The approach ensures that the network can maintain optimal performance while managing large datasets, ultimately contributing to the overall stability and reliability of the computerized production system.

Furthermore, this method provides the added advantage of enabling the system to handle peak loads more effectively. During periods of high data volume or network activity, the consolidation strategy ensures that the system can cope with increased demands without compromising performance. By aggregating data before transmission, the system can allocate resources more efficiently and maintain smooth operation even under challenging conditions.

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The strategy of transferring a predetermined volume of industrial data or a specified number of log records to a consolidation server is a key aspect of data management within computerized production systems. This approach optimizes resource usage, reduces network strain, and ensures efficient data transmission, ultimately contributing to a more robust and effective production system.

Another effective strategy for managing data within a computerized production system involves the routine transfer of all collected industrial data to the consolidation server at predefined time intervals. This method ensures that, regardless of the volume of data accumulated, all available information is transmitted to the consoledation server at regular intervals. This approach is particularly advantageous for systems that require continuous data collection and integration, as it facilitates timely updates and comprehensive analysis.

By adhering to a fixed schedule, this strategy guarantees that the system remains up-to-date with the latest data, which is crucial for real-time analysis and decision-making. The regular transmission of data ensures that the consolidation server consistently receives fresh information, enabling it to perform accurate and timely analyses. This continuous flow of data supports effective monitoring and management of the production system, providing stakeholders with the information necessary to make well-informed decisions based on the most current data available.

Moreover, this method enhances the system's ability to integrate and analyze data in a timely manner. With data being transferred at regular intervals, the consolidation server can aggregate information from various sources and generate insights that reflect the current state of the production system. This approach not only aids in maintaining the system's relevance but also improves its responsiveness to emerging trends or issues within the production environment.

A further strategy involves scheduling the transmission of industrial data to occur only at specific times, such as daily, weekly, or hourly. This method is designed to optimize the utilization of network resources by planning data transfers to take place at predetermined intervals. By scheduling data transmissions, the system can more effecttively manage network traffic, thereby reducing the risk of congestion during peak usage periods.

This approach is especially valuable for systems where consistent and predictable data transmission is essential. By avoiding data transfers during times of high network activity, this strategy helps to balance the network load and improve overall performance. It ensures that network resources are allocated efficiently, preventing potential bottlenecks and maintaining smooth operation of the computerized production system.

The routine transfer of all collected industrial data at specified time intervals, as well as the scheduling of data transmissions at specific times, are integral strategies for optimizing data management within computerized production systems. These approaches facilitate continuous data collection, ensure timely updates, and enhance network resource utilization, ultimately contributing to a more effective and responsive production environment.

The most demanding strategy for managing data in a computerized production

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system involves the immediate transfer of data as each new record is read from the logs. This approach, essential for applications that require real-time information for precise monitoring and decision-making, ensures that the most current data is always available (Fig. 6). However, it places significant demands on both network and computing resources due to the continuous and instantaneous transmission of new records.

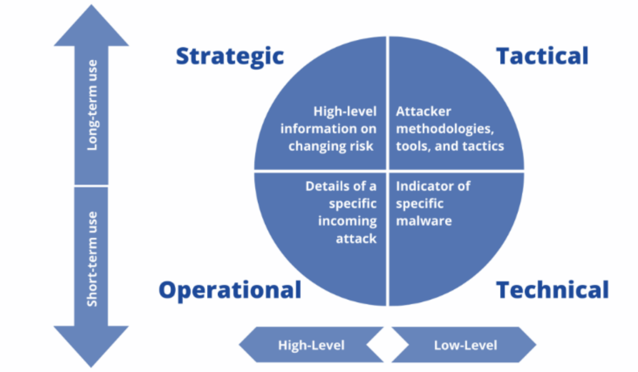

Fig.6. Types of threat intelligence.

The real-time data transfer method is crucial for systems that must provide up-to-the-minute information to maintain operational accuracy and support timely decisions. While this approach ensures data freshness, it can substantially increase the workload on the system. To manage this effectively, it is imperative to have a robust and scalable infrastructure capable of handling the continuous data flow. Such infrastructure must be designed to accommodate high data volumes and prevent potential bottlenecks that could disrupt system performance.

To optimize system efficiency and manage the increased workload, agents can implement a load-balancing mechanism. This mechanism involves distributing tasks between the primary computerized production system and additional dedicated computers. By sharing the data collection and preprocessing responsibilities, this approach enhances the utilization of computing resources and improves overall system performance.

A key benefit of this load-balancing mechanism is the ability to remotely access and process some journal entries. This capability allows for more efficient management of data processing tasks, reduces the likelihood of delays, and ensures smoother operation of the system. The distribution of tasks helps prevent any single component of the system from becoming overwhelmed, thereby maintaining optimal performance and stability.

While the immediate transfer of data ensures real-time updates and supports accurate decision-making, it requires a highly capable infrastructure to manage the increased demands on network and computing resources. Employing a load-balancing mechanism further enhances system efficiency by optimizing resource utilization and ensuring effective management of data processing workloads.

Moreover, agents within the computerized production system are engineered for versatility, enabling them to function across diverse platforms and gather data from a variety of registration logs. This adaptability is critical for sustaining the continuous operation of the system. The system's inherent flexibility facilitates the addition of new agents or modifications to existing ones without necessitating a complete system reboot. This capability is vital for maintaining operational stability and continuity.

The system's design supports seamless integration and scalability, allowing it to evolve in response to changing data needs and environmental conditions. This flexibility ensures that the system remains resi-

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lient and capable of adapting to new challenges. By accommodating the dynamic nature of industrial data requirements and incorporating updates without interrupting operations, the system can effectively manage and respond to emerging issues, thereby sustaining its operational efficiency and effectiveness over time.

Consolidation Server in computerized production system

In a computerized production system, the consolidation server serves as the central hub, crucial for the efficient operation and management of industrial data. This server is tasked with receiving data collected by various agents, converting this data into a standardized internal format, and then storing it in the system's centralized repository. The consolidation server plays a fundamental role in ensuring that the data flow within the system is both smooth and efficient, thereby impacting the overall performance, speed, and stability of the computerized production system.

The efficiency of the consolidation server is dependent on two primary factors. Firstly, the process of integrating new log file data is essential. This integration involves several key steps: ensuring that the data is formatted correctly, verifying its accuracy, and integrating it into the existing system without causing disruptions. Effective integration requires robust mechanisms to handle large volumes of data efficiently, maintaining data integrity and consistency throughout the process. This is crucial for preventing data bottlenecks and ensuring that the system remains responsive and reliable.

Secondly, the extraction and analysis of critical industrial data from the centralized repository are vital for supporting decision-making processes. This involves retrieving relevant information, analyzing it to derive actionable insights, and presenting it in a format that facilitates informed decision-making. The tools and techniques used for data extraction and analysis must be sophisticated enough to handle complex queries and large datasets, providing timely and accurate information to support operational and strategic decisions.

To ensure the consolidation server operates effectively, it must address several challenges. For instance, the server must be capable of managing the high volume and variety of data generated by different agents. It must also support real-time data processing and analytics, which requires significant computational resources and efficient data management practices. Additionally, the server must be designed to handle potential issues such as data corruption, system failures, or security breaches, ensuring that the data remains secure and accessible.

Moreover, the consolidation server should be scalable to accommodate growing data volumes and evolving system requirements. This means that the server's architecture must support expansion and upgrades without compromising performance or stability. Implementing load balancing and redundancy strategies can further enhance the server's reliability and efficiency, ensuring that it can handle peak loads and maintain continuous operation.

The consolidation server is a critical component of a computerized production system. Its effectiveness in managing the integration of new data and the extraction of valuable insights directly influences the overall performance and stability of the system. Ensuring that the consolidation

server operates efficiently requires a combination of robust data integration mechanisms, advanced analysis tools, and scalable infrastructure to support the system's ongoing needs and challenges.

In a computerized production system, the analysis process necessitates the swift and effective retrieval of industrial data from the central repository. This process typically involves accessing all records accumulated over a designated time frame from a centralized location. To address this requirement efficiently, it is crucial for the computerized production system to organize and store records in the repository according to a chronological sequence. Such an arrangement not only facilitates the streamlined extraction of crucial industrial data but also significantly enhances the system's analytical capabilities.

By maintaining a time-ordered structure for the stored records, the system ensures that data retrieval is both straightforward and efficient. This chronological organization simplifies the process of accessing historical data and supports more accurate and timely analyses. As a result, the system can deliver essential industrial information without undue delays, improving the overall effectiveness of data analysis and supporting better-informed decision-making.

Furthermore, this method of organizing data ensures that all relevant information is readily available when needed, minimizing potential disruptions and optimizing the system's performance. It allows for a more organized and systematic approach to data management, thereby enhancing the reliability and speed of the analytical process.

Storing industrial data in a time-sequenced format within the repository is crucial for optimizing both the speed of data retrieval and the accuracy of historical data analysis in a computerized production system. By systematically organizing records in chronological order, the system achieves several key benefits.

Firstly, chronological organization of data ensures that the retrieval processes are highly efficient, allowing for swift access to relevant industrial information. This is especially important in dynamic industrial environments where timely information is critical for operational decisions. The structured arrangement of records means that data can be accessed with minimal delay, avoiding the inefficiencies and potential errors associated with unstructured or non-sequential data storage.

Secondly, the chronological arrangement enhances the accuracy of historical data analysis. With records organized by time, it becomes easier to track and analyze trends, identify patterns, and conduct longitudinal studies. This systematic approach supports more precise and reliable analytical outcomes, as it allows for a clear and coherent view of data evolution over time.

Moreover, this method of data organization supports the overall analytical capabilities of the computerized production system. By facilitating efficient data extraction and analysis, the system can better support informed decision-making. Decision-makers can quickly access historical data to make evidence-based choices, anticipate future trends, and respond effectively to emerging issues.

The time-sequenced storage of industrial data not only improves the efficiency and accuracy of data retrieval but also enhances the system's analytical performance. This, in turn, supports more timely

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and informed decision-making within the industrial context, ultimately contributing to better operational outcomes and strategic planning.

Moreover, the structured approach to industrial data storage in a time-sequenced format significantly enhances the consistency and reliability of industrial data processing within a computerized production system. By systematically organizing data chronologically, this method mitigates the risk of errors and discrepancies that often arise from disorganized or unordered data. This not only ensures the accuracy of the data but also enhances the overall integrity of the analytical processes.

A well-organized, time-sequenced repository helps maintain a clear and coherent dataset, which is crucial for performing reliable data analysis. It allows for easier identification and correction of potential issues, such as missing or duplicated records, and prevents the confusion that can occur when data is not systematically arranged. This structured organization supports the seamless integration of new data and facilitates straightforward historical comparisons.

Additionally, the time-ordered arrangement of industrial data minimizes the latency in data retrieval, ensuring that all necessary information is delivered promptly without significant delays. This real-time capability is essential for analysts and decision-makers who need access to the most relevant and current industrial data. The reduced lag time in data availability means that decisions can be made more quickly and based on the most up-to-date information, which is crucial for maintaining operational efficiency and responding to dynamic industrial conditions.

Organizing industrial data in a chronological manner within the repository is not just a matter of convenience but a strategic approach that enhances the efficiency of data analysis in a computerized production system. This method simplifies the extraction and processing of data, improves the system's analytical capabilities, and ensures that critical industrial information is accessible in a timely manner. As a result, it supports more effective decision-making, operational efficiency, and the overall success of industrial processes.

The structured, time-sequenced storage of industrial data is fundamental to achieving high levels of accuracy, efficiency, and reliability in a computerized production system. This approach facilitates more effective data management, quicker access to vital information, and robust analysis, thereby underpinning successful decision-making and optimizing operational performance.

In a computerized production system, efficient storage and management of journal records are achieved by distributing these records across multiple files. This organizational strategy involves creating two main types of files: primary files for core parameters and additional files for supplementary parameters. Additionally, dictionary files are utilized to store the actual values associated with these parameters. The primary files maintain unique identifiers for each parameter, while the dictionary files translate these identifiers into their corresponding real-world values. This structured approach ensures that the system can handle and process data more effectively.

The organization of records into these files enhances the overall operational efficiency of the computerized production system. By separating core and supplementary

parameters, the system reduces the load on the industrial data repository and speeds up the processing of analytical tasks. The architecture allows for streamlined access and management of data, reducing the risk of data congestion and improving response times for data retrieval and analysis.

The consolidation server in this computerized production system plays a critical role in managing, processing, and analyzing industrial data. As a sophisticated component, the server is designed to handle the large volumes of data collected by various agents within the system. It enables the efficient storage and rapid analysis of substantial amounts of industrial data, which is crucial for maintaining the performance and reliability of the security monitoring system.

This server's advanced capabilities contribute significantly to the overall effectiveness of the computerized production system. By facilitating the management, storage, and swift analysis of industrial data, the consolidation server enhances the system's ability to monitor and respond to security threats effectively. The ability to process data quickly and accurately supports timely decision-making and helps in maintaining the integrity and reliability of the system.

Moreover, the consolidation server's efficiency in handling and analyzing data helps to prevent potential bottlenecks in data processing. This proactive approach ensures that the security monitoring system operates smoothly, with minimal delays and optimal performance. The comprehensive data management capabilities of the consolidation server are integral to supporting effective monitoring, analysis, and response within the computerized production system, ultimately contributing to enhanced operational efficiency and security.

Mathematical model of data analysis in computerized production system.

In a computerized production system, the consolidation server and storage system do not impose restrictions on the methods and mechanisms that can be used for data analysis. In other words, a computerized manufacturing system provides the opportunity to use various analytical tools for data analysis. Analysis methods in a computerized manufacturing system include statistical analysis, and may include functions such as identifying associative rules, detecting anomalies, and exceptions.

To build a mathematical model of data analysis in a computerized production system based on the provided text, we'll break down the concepts described and define the components, relationships, and processes involved. Here's a structured approach to constructing the model:

Computerized Production System (CPS): The system consists of various components, including a consolidation server and a storage system, which support data analysis without imposing specific restrictions on the methods used.

The data D generated or stored in the CPS. This data can be of various types and is subject to analysis. A set of different analysis methods M_i, where i represents a specific method. M_1: Statistical Analysis; M_2: Identification of Associative Rules; M_3: Anomaly Detection; M_4: Exception Detection.

The result or outcome O_i of applying a specific analysis method M_i to the data D. Consolidation server $\boldsymbol{S_c}$ facilitates the consolidation and processing of data without imposing restrictions on the analysis methods. Storage system S_s stores data and

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allows access for analysis.

The data D is processed by applying various analysis methods M_i. The general form can be expressed as:

$$O_i = M_i(D)$$

where O_i is the output resulting from applying method M_i on data D. M_i is the analytical function representing the method applied.

The CPS does not impose restrictions on the choice of methods M_i. Therefore, any method M_i can be applied, implying: $M_i \in \{M_1, M_2, M_3, M_4, \dots\}$

This set is open, meaning new methods can be included without restriction. Statistical Analysis $M_1(D)$ could involve calculating descriptive statistics, inferential statistics, or applying specific statistical models (e.g., regression analysis, hypothesis testing).

Associative Rule Identification $M_2(D)$ function identifies patterns or rules that indicate associations between variables within the data, often using algorithms like Apriori or FP-Growth.

Anomaly Detection $M_3(D)$ identifies data points or patterns that deviate significantly from the norm. Common approaches include statistical methods, clustering-based techniques, or machine learning models.

Exception Detection $M_4(D)$ process focuses on identifying cases that do not conform to expected patterns, often using threshold-based methods or rule-based systems.

Scalability S - the model should account for the ability to scale with increasing data D. Therefore, S is a factor that influences the performance and complexity of the methods M_i. $S = f(D, M_i)$ where f is a function describing how the system scales based on the size of data D and the complexity of methods M_i.

The overall system can be summarized by the following model:

$$O = \sum_i M_i(D) \ where \ M_i \in \{M_1, M_2, M_3, M_4, \dots\}$$

and the system scalability is given by $S = f(D, M_i)$.

This mathematical model captures the flexibility of the computerized production system in analyzing data using various methods without restrictions. The output O is a composite result of multiple analysis methods applied to the data D, and the system's scalability S depends on the data size and chosen analysis methods.

This model can be further expanded or refined based on specific use cases, data types, or additional constraints in the computerized production system.

Discussion. The specialized storage system in a computerized production environment ensures the organized storage of industrial data. This system architecture is designed in a hierarchical, tree-like structure, comprising the following components:

Core Structure of the Computerized Production System: The root of the storage system in a computerized production environment consists of directories named after domains. Each domain directory contains subdirectories relevant to its specific domain within the computerized production system. This hierarchical organization helps efficiently manage and navigate through extensive data by categorizing it according to domains.

Computerized Production System Catalogs: Within the computerized pro-

duction system, each computer catalog contains log files derived from the respective computer system. These log files are organized by time, such as daily logs, facilitating more precise analysis and search of industrial data over time. This time-based organization simplifies the process of tracking and analyzing data trends and patterns with greater accuracy.

Dictionary Files in the Computerized Production System: Dictionary files may be located within the data storage area of the computerized production system. These files store the actual values of parameters and provide the capability to retrieve these values through identifiers. Dictionary files are essential for translating identifiers into their corresponding real-world values, enhancing data interpretation and utilization.

Efficient Data Storage in the Computerized Production System:

Storing data in this structured format ensures rapid and efficient searching and retrieval of industrial information. For example, when applying digital technology, it is often possible to work with only core parameters to quickly fill in certain facts.

If additional parameters are necessary, retrieving only their identifiers instead of the actual values can be an effective option. In this context, organizing files systematically within the computerized production system improves the system's efficiency and ensures swift access to industrial data, thereby supporting effective data management and analysis.

Conclusion. In computerized production systems, raw data is managed from registration logs, data is presented in time intervals. In order to protect against internal attacks, a mathematical model was created to effectively control the behavior of employees in computerized production systems. The proposed architecture is proposed to build a mathematical model of analysis and synthesis of collected data about the subject's activity in the computerized production system based on associative rules. It is presented to the administrator visually as a network of dependencies, and anomalies in the behavior of system participants can be analyzed.

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